ENERGY STAR® PortfolioManager®

Technical Reference

ENERGY STAR Score for Residence Halls/Dormitories in the United States

OVERVIEW

The ENERGY STAR Score for Residence Halls/Dormitories applies to buildings associated with educational institutions (residence halls/dormitories) or military facilities (barracks) which offer multiple accommodations for long-term residents. The objective of the ENERGY STAR score is to provide a fair assessment of the energy performance of a property relative to its peers, taking into account the climate, weather, and business activities at the property. To identify the aspects of building activity that are significant drivers of energy use and then normalize for those factors, a statistical analysis of the peer building population is performed. The result of this analysis is an equation that will predict the energy use of a property, based on its experienced business activities. The energy use prediction for a building is compared to its actual energy use to yield a 1 to 100 percentile ranking of performance, relative to the national population.

- **Property Types.** The ENERGY STAR score for residence halls/dormitories applies to buildings associated with educational institutions (residence halls/dormitories) or military facilities (barracks) which offer multiple accommodations for long-term residents. The score applies to individual buildings only and is not available for campuses.
- **Reference Data.** The analysis for residence halls/dormitories is based on data from the Department of Energy, Energy Information Administration's 1999 Commercial Building Energy Consumption Survey (CBECS).
- **Adjustments for Weather and Business Activity.** The analysis includes adjustments for:
  - Building Size
  - Number of Guest/Occupant Rooms
  - Weather and Climate (using Heating and Cooling Degree Days, retrieved based on Zip code)
  - Percent of the Building that is Heated and Cooled
- **Release Date.** The ENERGY STAR score for residence halls/dormitories was released in January 2004.

This document presents details on the development of the 1 - 100 ENERGY STAR score for residence hall/dormitories. More information on the overall approach to develop ENERGY STAR scores is covered in our Technical Reference for the ENERGY STAR Score, available at www.energystar.gov/ENERGYSTARScore. The subsequent sections of this document offer specific details on the development of the ENERGY STAR score for residence halls/dormitories:

REFERENCE DATA & FILTERS

For the ENERGY STAR score for residence hall/dormitory properties, the reference data used to establish the peer building population in the United States is based on data from the Department of Energy, Energy Information Administration's (EIA) 1999 Commercial Building Energy Consumption Survey (CBECS). Detailed information on this survey, including complete data files, is available at: http://www.eia.doe.gov/emeu/cbecs/contents.html.

To analyze the building energy and operating characteristics in this survey data, four types of filters are applied to define the peer group for comparison and to overcome any technical limitations in the data: Building Type Filters, Program Filters, Data Limitation Filters, and Analytical Filters. A complete description of each of these categories is provided in our Technical Reference for the ENERGY STAR Score, at www.energystar.gov/ENERGYSTARScore. ***Figure 1*** presents a summary of each filter applied in the development of the ENERGY STAR score for residence halls/dormitories and the rationale behind the filter. After all filters are applied, the remaining data set has 79 properties.

Figure 1 – Summary of Filters for the ENERGY STAR Score for Residence Halls/Dormitories

Condition for Including an Observation in the Analysis	Rationale
PBAPLUS7= 9	Building Type Filter – CBECS defines building types according to the variable "PBAPLUS7." Residence Hall/Dormitory buildings are coded as PBAPLUS7= 9.
Source energy use intensity (kBtu/ft^2-yr) must be greater than 40 and less than 425 kBtu/ft^2-yr	Analytical Filter – Values determined to be statistical outliers.

Of the filters applied to the reference data, some result in constraints on calculating a score in Portfolio Manager and others do not. Building Type and Program Filters are used to limit the reference data to include only properties that are eligible to receive a score in Portfolio Manager, and are therefore related to eligibility requirements. In contrast, Data Limitation Filters account for limitations in the data availability, but do not apply in Portfolio Manager. Analytical Filters are used to eliminate outlier data points or different subsets of data, and may or may not affect eligibility. In some cases, a subset of the data will have different behavior from the rest of the properties (e.g., office buildings smaller than 5,000 ft^2 do not behave the same way as larger buildings), in which case an Analytical Filter will be used to determine eligibility in Portfolio Manager. In other cases, Analytical Filters exclude a small number of outliers with extreme values that skew the analysis, but do not affect eligibility requirements. A full description of the criteria you must meet to get a score in Portfolio Manager is available at www.energystar.gov/EligibilityCriteria.

Related to the filters and eligibility criteria described above, another consideration is how Portfolio Manager treats properties that are situated on a campus. The main unit for benchmarking in Portfolio Manager is the property, which may be used to describe either a single building or a campus of buildings. The applicability of the ENERGY STAR score depends on the type of property. For residence hall/dormitory properties, the score is based on individual buildings, because the primary function of the residence hall/dormitory is contained within a single building and because the properties included in the reference data are single buildings. In cases where multiple residence halls/dormitories are situated together, each individual building can receive its own ENERGY STAR score, but the group of buildings together cannot earn a score.

VARIABLES ANALYZED

To normalize for differences in business activity, we perform a statistical analysis to understand what aspects of building activity are significant with respect to energy use. The filtered reference data set described in the previous section is analyzed using a weighted ordinary least squares regression, which evaluates energy use relative to business activity (e.g., guest/occupant rooms). This linear regression yields an equation that is used to compute energy use (also called the dependent variable) based on a series of characteristics that describe the business activities (also called independent variables). This section details the variables used in the statistical analysis for residence halls/dormitories.

Dependent Variable

The dependent variable is what we try to predict with the regression equation. For the residence hall/dormitory analysis, the dependent variable is energy consumption expressed as the natural log of source energy use, or Ln (source energy). The regressions analyze the key drivers of Ln (source energy) – those factors that explain the variation in the natural log of source energy in residence halls/dormitories.

Independent Variables

The reference survey collects numerous property operating characteristics that were identified as potentially important for residence halls/dormitories. These include characteristics such as the total square footage, the number of guest/occupant rooms, the percent of the building that is heated and cooled, and the number of heating and cooling degree days.

We perform extensive review on all operational characteristics available in the data, in accordance with the criteria for inclusion in Portfolio Manager.[1] In addition to reviewing each characteristic individually, characteristics are reviewed in combination with each other (e.g., Heating Degree Days times Percent Heated). As part of the analysis, some variables are reformatted to reflect the physical relationships of building components. In addition, based on analytical results and residual plots, variables are examined using different transformations (such as the natural logarithm). The analysis consists of multiple regression formulations. These analyses are structured to find the combination of statistically significant operating characteristics that explain the greatest amount of variance in the dependent variable: Ln (source energy).

The final regression equation includes the following variables:

- Natural log of gross square foot
- Natural log of number of guest/occupant rooms
- Heating degree days times Percent of the building that is heated
- Cooling degree days times Percent of the building that is cooled

These variables are used together to compute the predicted Ln (source energy) for residence halls/dormitories. The predicted Ln (source energy) is the mean Ln (source energy) for a hypothetical population of buildings that share the same values for each of these variables. That is, the mean energy use for a building that operates just like your building.

[1] For a complete explanation of these criteria, refer to our Technical Reference for the ENERGY STAR Score, at www.energystar.gov/ENERGYSTARScore.

Testing

Finally, we test the regression equation using actual residence hall/dormitory buildings, using supplemental data provided by ENERGY STAR partners. This provides another set of buildings to examine in addition to the CBECS data, to see the average ENERGY STAR scores and distributions, and to assess the impacts and adjustments. This analysis provides a second level of confirmation that the final regression equation produces robust results that are unbiased with respect to the key operational characteristics such as building size, guest/occupant rooms, and heating and cooling degree days.

It is important to reiterate that the final regression equation is based on the nationally representative reference data, not data previously entered into Portfolio Manager.

REGRESSION EQUATION RESULTS

The final regression is a weighted ordinary least squares regression across the filtered data set of 79 observations. The dependent variable is Ln (source energy). Each independent variable is presented in ***Figure 2***. The final equation is presented in ***Figure 3***. All variables in the regression equation are significant at the 95% confidence level or better, as shown by the significance levels (a p-level of less than 0.05 indicates 95% confidence), with the exception of guest/occupant rooms, which has a lower level of significance (75%). However, given the physical relationship between guest/occupant room and energy consumption, this result was considered acceptable, and therefore guest/occupant rooms was retained in the analysis.

The regression equation has a coefficient of determination (R^2) value of 0.8834, indicating that this equation explains 88.34% of the variance in Ln (source energy) for residence hall/dormitory buildings. This is an excellent result for a statistically based energy model.

Detailed information on the ordinary least squares regression approach is available in our Technical Reference for the ENERGY STAR Score, at www.energystar.gov/ENERGYSTARScore.

Figure 2 - Descriptive Statistics for Variables in Final Regression Equation

Variable	Mean	Minimum	Maximum
Ln (Source energy) (kBtu)	15.717	12.584	18.699
Ln (Square Foot)	10.705	8.161	13.653
Ln (Number of Rooms)	4.417	1.386	6.397
Heating Degree Days x Percent Heated	4575	116.2	7339
Cooling Degree Days x Percent Cooled	510.3	0.000	3162

Figure 3 - Final Regression Results

Summary				
Dependent Variable		Ln (Source Energy) (kBtu)		
Number of Observations in Analysis		79		
R^2 value		0.8834		
Adjusted R^2 value		0.8771		
F Statistic		140.1		
Significance (p-level)		0.000		
	Unstandardized Coefficients	**Standard Error**	**T value**	**Significance (p-level)**
Constant	4.99455	0.5671	8.81	<.0001
Ln (Square Foot)	0.91308	0.07724	11.82	<.0001
Ln (Number of Rooms)	0.09455	0.08141	1.16	0.2492
Heating Degree Days x Percent Heated	0.00009774	0.00003297	2.96	0.0041
Cooling Degree Days x Percent Cooled	0.00016279	0.08141	2.14	0.0357

Notes:
- *The regression is a weighted ordinary least squares regression, weighted by the CBECS variable "ADJWT8".*

ENERGY STAR SCORE LOOKUP TABLE

The final regression equation (presented in ***Figure 3***) yields a prediction of Ln (source energy) based on a building's operating characteristics. Some buildings in the reference data sample use more energy than predicted by the regression equation, while others use less. The *actual* Ln (source energy) of each reference data observation is divided by its *predicted* Ln (source energy) to calculate an energy efficiency ratio:

$$Energy\ Efficiency\ Ratio = \frac{Actual\ Ln\ (source\ energy)}{Predicted\ Ln\ (source\ energy)}$$

A lower efficiency ratio indicates that a building uses less energy than predicted, and consequently is more efficient. A higher efficiency ratio indicates the opposite. For each building, the ratio is expressed in terms of a normalized Ln (source energy) to represent the value for Ln (source energy) that the building would have if it were average. This normalized energy use is obtained by multiplying the efficiency ratio by the mean value of Ln (source energy):[2]

$$Normalized\ Ln\ (Source\ Energy) = Energy Efficiency\ Ratio \times 15.717$$

[2] The mean value of Ln (source energy) is determined by the dataset and is presented in ***Figure 2***. It is 15.717.

The normalized Ln (source energy) values are sorted from smallest to largest and the cumulative percent of the population at each energy value is computed. A smooth curve is fitted to the data using a two parameter gamma distribution. The fit is performed in order to minimize the sum of squared differences between each building's actual percent rank in the population and each building's percent rank with the gamma solution. The fit is performed with the constraint that the gamma value of Ln (source energy) at an ENERGY STAR score of 75 must equal the actual value of Ln (source energy) at 75.

The final gamma shape and scale parameters are used to calculate the normalized Ln (source energy) value at each percentile (1 to 100) along the curve. For example, the normalized Ln (source energy) value on the gamma curve at 1% corresponds to a score of 99; only 1% of the population has a value this small or smaller. The normalized Ln (source energy) value on the gamma curve at the value of 25% will correspond to the normalized Ln (source energy) value for a score of 75; only 25% of the population has normalized Ln (source energy) values this small or smaller. The complete lookup table is presented in ***Figure 4***.

Figure 4 – ENERGY STAR Score Lookup Table for Residence Halls/Dormitories

ENERGY STAR Score	Cumulative Percent	Normalized Ln (Source Energy) > =	<
100	0%	0.0000	14.6453
99	1%	14.6453	14.7103
98	2%	14.7103	14.7713
97	3%	14.7713	14.8283
96	4%	14.8283	14.8823
95	5%	14.8823	14.9323
94	6%	14.9323	14.9793
93	7%	14.9793	15.0233
92	8%	15.0233	15.0643
91	9%	15.0643	15.1033
90	10%	15.1033	15.1393
89	11%	15.1393	15.1733
88	12%	15.1733	15.2053
87	13%	15.2053	15.2353
86	14%	15.2353	15.2633
85	15%	15.2633	15.2893
84	16%	15.2893	15.3143
83	17%	15.3143	15.3383
82	18%	15.3383	15.3603
81	19%	15.3603	15.3813
80	20%	15.3813	15.4003
79	21%	15.4003	15.4193
78	22%	15.4193	15.4373
77	23%	15.4373	15.4543
76	24%	15.4543	15.4703
75	25%	15.4703	15.4863
74	26%	15.4863	15.5013
73	27%	15.5013	15.5153
72	28%	15.5153	15.5293
71	29%	15.5293	15.5423
70	30%	15.5423	15.5553
69	31%	15.5553	15.5683
68	32%	15.5683	15.5813
67	33%	15.5813	15.5933
66	34%	15.5933	15.6053
65	35%	15.6053	15.6173
64	36%	15.6173	15.6283
63	37%	15.6283	15.6403
62	38%	15.6403	15.6513
61	39%	15.6513	15.6633
60	40%	15.6633	15.6743
59	41%	15.6743	15.6853
58	42%	15.6853	15.6963
57	43%	15.6963	15.7073
56	44%	15.7073	15.7193
55	45%	15.7193	15.7303
54	46%	15.7303	15.7413
53	47%	15.7413	15.7523
52	48%	15.7523	15.7633
51	49%	15.7633	15.7743

ENERGY STAR Score	Cumulative Percent	Normalized Ln (Source Energy) >=	<
50	50%	15.7743	15.7853
49	51%	15.7853	15.7963
48	52%	15.7963	15.8083
47	53%	15.8083	15.8193
46	54%	15.8193	15.8303
45	55%	15.8303	15.8413
44	56%	15.8413	15.8523
43	57%	15.8523	15.8643
42	58%	15.8643	15.8753
41	59%	15.8753	15.8863
40	60%	15.8863	15.8973
39	61%	15.8973	15.9083
38	62%	15.9083	15.9203
37	63%	15.9203	15.9313
36	64%	15.9313	15.9423
35	65%	15.9423	15.9533
34	66%	15.9533	15.9653
33	67%	15.9653	15.9763
32	68%	15.9763	15.9883
31	69%	15.9883	15.9993
30	70%	15.9993	16.0113
29	71%	16.0113	16.0233
28	72%	16.0233	16.0353
27	73%	16.0353	16.0473
26	74%	16.0473	16.0593
25	75%	16.0593	16.0723
24	76%	16.0723	16.0853
23	77%	16.0853	16.0993
22	78%	16.0993	16.1123
21	79%	16.1123	16.1263
20	80%	16.1263	16.1413
19	81%	16.1413	16.1563
18	82%	16.1563	16.1723
17	83%	16.1723	16.1893
16	84%	16.1893	16.2063
15	85%	16.2063	16.2243
14	86%	16.2243	16.2433
13	87%	16.2433	16.2633
12	88%	16.2633	16.2853
11	89%	16.2853	16.3073
10	90%	16.3073	16.3313
9	91%	16.3313	16.3563
8	92%	16.3563	16.3833
7	93%	16.3833	16.4123
6	94%	16.4123	16.4423
5	95%	16.4423	16.4743
4	96%	16.4743	16.5093
3	97%	16.5093	16.5453
2	98%	16.5453	16.5853
1	99%	16.5853	>16.5853

EXAMPLE CALCULATION

As detailed in our Technical Reference for the ENERGY STAR Score, at www.energystar.gov/ENERGYSTARScore, there are five steps to compute a score. The following is a specific example for the score for residence halls/dormitories:

1 User enters building data into Portfolio Manager

- 12 months of energy use information for all energy types (annual values, entered in monthly meter entries)
- Physical building information (size, location, etc.) and use details describing building activity (rooms, etc.)

Energy Data	Value
Electricity	271,500 kWh
Natural gas	5,900 therms

Property Use Details	Value
Gross floor area (ft^2)	44,000
Number of rooms	80
Percent of the building that is heated	100%
Percent of the building that is cooled	100%
HDD (provided by Portfolio Manager, based on Zip code)	4500
CDD (provided by Portfolio Manager, based on Zip code)	1000

2 Portfolio Manager computes the actual Ln (source energy)

- Total energy consumption for each fuel is converted from billing units into site energy and source energy
- Source energy values are added across all fuel types
- The natural log of total source energy consumption is computed

Computing Actual Ln (Source Energy)

Fuel	Billing Units	Site kBtu Multiplier	Site kBtu	Source kBtu Multiplier	Source kBtu
Electricity	271,500 kWh	3.412	926,358	3.14	2,908,764
Natural gas	5,900 therms	100	590,000	1.05	619,500
				Total Source Energy (kBtu)	3,528,264
				Actual Ln (Source Energy) (kBtu)	**15.076**

3 Portfolio Manager computes the predicted Ln (source energy)

- Using the property use details from Step 1, Portfolio Manager computes each building variable value in the regression equation (determining the natural log or density as necessary).
- The variables are multiplied by the coefficients from the regression equation to obtain a predicted Ln (source energy).

Computing Predicted Ln (Source Energy)

Variable	Actual Building Value	Coefficient	Coefficient * Variable
Constant	--	4.995	4.995
Ln (Square Foot)	10.69	0.9131	9.763
Ln (Number of Rooms)	4.382	0.0946	0.414
HDD x Percent Heated	4500	0.0001	0.440
CDD x Percent Cooled	500	0.0002	0.081
		Predicted Ln (Source Energy) (kBtu)	***15.693***

4 Portfolio Manager computes the energy efficiency ratio

- The ratio equals the actual Ln (source energy) (Step 2) divided by predicted Ln (source energy) (Step 3)
- Ratio = 15.076 / 15.693 = 0.9607

5 Portfolio Manager uses the efficiency ratio to assign a score via a lookup table

- The ratio from Step 4 is converted into normalized Ln (source energy)
  - Normalized Ln (source energy) = energy efficiency ratio * mean Ln (source energy)
  - Mean Ln (source energy) is provided in ***Figure 2*** = 15.717
  - Normalized Ln (source energy) = 0.9607 * 15.717 = 15.100
- This value is then then used to identify the score from the lookup table
- A normalized value of 15.100 is greater than 15.0643 and less than 15.1033.
- ***The ENERGY STAR score is 91.***